Chapter 1

Introduction: Biology Today

- We are living in a golden age of biology.
- Scientists are studying a myriad of questions that are relevant to our lives.
  - How can errors in cell growth lead to cancer?
  - How do plants trap solar energy?
  - How do living creatures form ecological networks and how do human activities disrupt them?

Biology and Society:
Biology All Around Us

  - How did the great diversity of life on Earth evolve from the first microbes and how does such evolution have an impact on human health?
  - How do mutations in genes lead to disease?
  - How can DNA—the molecular basis of heredity—be used in forensic investigations?

Figure 1.0

THE SCOPE OF LIFE

The Properties of Life

- **Biology** is the scientific study of life.
- The study of biology encompasses
  - a wide scale of size and
  - a huge variety of life, both past and present.

Figure 1.1a
Figure 1.1b
Figure 1.1ba
Figure 1.1bb
Figure 1.1bc
Figure 1.1bd
Figure 1.1be
Figure 1.1bf
Figure 1.1bg

Life at Its Many Levels

- Biologists explore life at levels ranging from the **biosphere** to the molecules that make up cells.

Figure 1.2-1
Figure 1.2-2
Figure 1.2-3
Figure 1.2a
Figure 1.2b
Figure 1.2c
Figure 1.2d
Figure 1.2e
Figure 1.2f
Figure 1.2g

Ecosystems

- Each organism interacts continuously with its environment.
  - Organisms interact continuously with the living and nonliving factors in the environment.
  - All the living organisms in a specific area, along with all of the nonliving factors with which they interact, form an **ecosystem**.

Ecosystems

- The dynamics of any ecosystem depend on two main processes:
  - recycling of chemical nutrients and
  - flow of energy.
- Within ecosystems
  - nutrients are recycled but
  - energy flows through.

Figure 1.3

Cells and Their DNA

- The cell is the level at which the properties of life emerge.
- Cells are the lowest level of structure that can perform all activities required for life.
- All organisms are composed of cells.
- Cells are the subunits that make up multicellular organisms such as humans and trees.
- All cells share many characteristics.
  - All cells are enclosed by a membrane that regulates the passage of materials between the cell and its surroundings.
  - Every cell uses DNA as its genetic information.
- We can distinguish two major types of cells:
  - The **prokaryotic cell** is
    - simpler and usually smaller and
    - characteristic of bacteria.
  - The **eukaryotic cell** is
    - subdivided by internal membranes into different functional compartments called organelles and

- found in plants and animals.

Figure 1.4
Figure 1.4a
Figure 1.4b

- All cells use DNA as the chemical material of **genes**, the units of inheritance that transmit information from parents to offspring.
- The chemical language of DNA
  - is common to all organisms and
  - consists of just four molecular building blocks with names that are abbreviated as A, G, C, T.

Figure 1.5

- Genetic engineering has transformed the pharmaceutical industry and extended millions of lives.

Figure 1.6

- The entire "book" of genetic instructions that an organism inherits is called its genome.
- The nucleus of each human cell packs a genome that is about 3 billion chemical letters long.

Life in Its Diverse Forms

- Diversity is a hallmark of life.
  - The diversity of known life includes about 1.8 million species that biologists have identified and named.
  - Estimates of the total number of species range from 10 million to over 100 million.

Figure 1.7

Grouping Species: The Basic Concept

- Biodiversity can be beautiful but overwhelming.
- Categorizing life into groups helps us deal with this complexity.
- Taxonomy is the branch of biology that names and classifies species.
  - It formalizes the hierarchical ordering of organisms into broader and broader groups.

The Three Domains of Life

- The three domains of life are
  - Bacteria,
  - Archaea, and
  - Eukarya.
- Bacteria and Archaea have prokaryotic cells.
- Eukarya have eukaryotic cells.

Figure 1.8
Figure 1.8a
Figure 1.8b
Figure 1.8ba
Figure 1.8bb
Figure 1.8bc
Figure 1.8bd
Figure 1.8be
Figure 1.8bf

Unity in the Diversity of Life

- Underlying the diversity of life is a striking unity, especially at the lower levels of biological organization.
  - For example, all life uses the genetic language of DNA.
- Biological evolution accounts for this combination of unity and diversity.

EVOLUTION:
BIOLOGY'S UNIFYING THEME

- The history of life is a saga of a constantly changing Earth billions of years old.
  - Fossils document this history.

Figure 1.9

- Life evolves.
  - Each species is one twig of a branching tree of life extending back in time through ancestral species more and more remote.
  - Species that are very similar, such as the brown bear and polar bear, share a more recent common ancestor.

Figure 1.10

The Darwinian View of Life

- The evolutionary view of life came into focus in 1859 when Charles Darwin published *On the Origin of Species by Means of Natural Selection.*
- Darwin's book developed two main points:
  - Species living today descended from a succession of ancestral species in what Darwin called "descent with modification," capturing the duality of life's
    - unity (descent) and

- diversity (modification).

- Natural selection is the mechanism for descent with modification.

Natural Selection

- Darwin was struck by the diversity of animals on the Galápagos Islands.

- He thought that adaptation to the environment and the origin of new species were closely related processes.

  - As populations separated by a geographic barrier adapted to local environments, they became separate species.

Figure 1.11
Figure 1.11a
Figure 1.11b

Darwin's Inescapable Conclusion

- Darwin synthesized the theory of natural selection from two observations that were neither profound nor original.

  - Others had the pieces of the puzzle, but Darwin could see how they fit together.

- Observation 1: Overproduction and competition

- Observation 2: Individual variation

- Conclusion: Unequal reproductive success

  - It is this unequal reproductive success that Darwin called **natural selection**.

  - The product of natural selection is adaptation.

- Natural selection is the mechanism of evolution.

Figure 1.12
Figure 1.12a
Figure 1.12b

Observing Artificial Selection

- Artificial selection is the selective breeding of domesticated plants and animals by humans.

- In artificial selection, humans do the selecting instead of the environment.

Figure 1.13a
Figure 1.13b
Figure 1.13ba
Figure 1.13bb

Observing Natural Selection

- There are many examples of natural selection in action.

  - In Galápagos finches, beak size becomes better suited to the size and shape of available seeds.

  - Antibiotic-resistance in bacteria evolves in response to the overuse of antibiotics.

- Darwin's publication of *The Origin of Species* fueled an explosion in biological research.

  - Evolution is one of biology's best demonstrated, most comprehensive, and longest-lasting theories.

  - Evolution is the unifying theme of biology.

THE PROCESS OF SCIENCE

- The word *science* is derived from a Latin verb meaning "to know."

  - **Science** is a way of knowing, based on inquiry.

  - Science developed from our curiosity about ourselves and the world around us.

THE PROCESS OF SCIENCE

- There are two main scientific approaches:

  - Discovery science is mostly about describing nature.

  - Hypothesis-driven science is mostly about explaining nature.

Discovery Science

- Science seeks natural causes for natural phenomena.

  - This limits the scope of science to the study of structures and processes that we can observe and measure directly or indirectly.

- The dependence on observations that people can confirm demystifies nature and distinguishes science from belief in the supernatural.

- Verifiable observations and measurements are the data of **discovery science**.

  - In biology, discovery science enables us to describe life at its many levels, from ecosystems down to cells and molecules.

Figure 1.14a
Figure 1.14b

Discovery Science
Hypothesis-Driven Science

- Once a hypothesis is formed, an investigator can use logic to test it.

  - A hypothesis is tested by performing an experiment to see whether results are as predicted.

- This deductive reasoning takes the form of "If…then" logic.

Figure 1.15-1
Figure 1.15-2
Figure 1.15-3

The Process of Science: Are Trans Fats Bad for You?

- One way to better understand how the process of science can be applied to real-world problems is to examine a case study, an in-depth examination of an actual investigation.
- Dietary fat comes in different forms.
- Trans fats are a non-natural form produced through manufacturing processes called hydrogenation.
- Trans fats
  - add texture,
  - increase shelf life, and
  - are inexpensive to prepare.
- A study of 120,000 female nurses found that a diet with high levels of trans fats nearly doubled the risk of heart disease.
- A hypothesis-driven study published in 2004
  - started with the **observation** that human body fat retains traces of consumed dietary fat,
  - asked the **question**, Would the adipose tissue of heart attack patients be different from a similar group of healthy patients?, and
  - formed the **hypothesis** that healthy patients' body fat would contain less trans fats than the body fat in heart attack victims.
- The researchers set up an **experiment** to determine the amounts of fat in the adipose tissue of 79 patients who had experienced a heart attack.
- They compared these patients to the data for 167 patients who had not experienced a heart attack.
- This is an example of a **controlled experiment**, in which the control and experimental groups differ only in one variable—the occurrence of a heart attack.
- The **results** showed significantly higher levels of trans fats in the bodies of the heart attack patients.
- You would do well to read nutrition labels and avoid trans fats as much as possible in your own diet.

Figure 1.16

Theories in Science

- What is a scientific theory, and how is it different from a hypothesis?
  - A scientific **theory** is much broader in scope than a hypothesis.
  - Theories only become widely accepted in science if they are supported by an accumulation of extensive and varied evidence.

Theories in Science

- Scientific theories are not the only way of "knowing nature."
- Science, religion, and art are very different ways of trying to make sense of nature.

The Culture of Science

- Scientists build on what has been learned from earlier research.
  - They pay close attention to contemporary scientists working on the same problem.
- Cooperation and competition characterize the scientific culture.
  - Scientists check the conclusions of others by attempting to repeat experiments.
  - Scientists are generally skeptics.

Figure 1.17

- Science has two key features that distinguish it from other forms of inquiry. Science
  - depends on observations and measurements that others can verify and
  - requires that ideas (hypotheses) are testable by experiments that others can repeat.

Science, Technology, and Society

- Science and technology are interdependent.
  - New technologies advance science.
  - Scientific discoveries lead to new technologies.
  - For example, the discovery of the structure of DNA about 60 years ago led to a variety of DNA technologies.

Figure 1.18

- Technology has improved our standard of living in many ways, but it is a double-edged sword.
- Technology that keeps people healthier has enabled the human population to double to 7 billion in just the past 40 years.
- The environmental consequences of this population growth may be devastating.

Evolution Connection:
Evolution in Our Everyday Lives

- Antibiotics are drugs that help cure bacterial infections.
- When an antibiotic is taken, most bacteria are typically killed.
- Those bacteria most naturally resistant to the drug can still survive.
- Those few resistant bacteria can soon multiply and become the norm and not the exception.
- The evolution of antibiotic-resistant bacteria is a huge problem in public health.
- Antibiotics are being used more selectively.
- Many farmers are reducing the use of antibiotics in animal feed.
- It is important to note that the adaptation of bacteria to an environment containing an antibiotic does not mean that the drug created the antibiotic resistance. Instead, the environment screened the heritable variations that already existed among the existing bacteria.

Figure 1.19
Figure 1.19a
Figure 1.19b
Figure 1.UN01
Figure 1.UN02
Figure 1.UN03
Figure 1.UN04
Figure 1.UN05